

2/PRTS

DT01 Rec'd PCT/PTC 22 DEC 2004

## Description

Waste heat steam generator

5 The invention relates to a waste heat steam generator which has a waste heat boiler which is operated by means of waste heat from a gas turbine.

Many modern power station installations, which are 10 equipped with gas turbines in order to generate electrical power, also have one or more waste heat boilers in order to use the hot exhaust gas from the gas turbines (which still has a high energy potential after being ejected from the gas turbine) for further 15 conversion to usable power. In this case, for example, the steam generated by the waste heat boiler is used for operation of at least one steam turbine, so the efficiency of a gas and steam power station such as this is higher than that of a pure gas turbine power 20 station.

In addition to the steam turbine, modern gas and steam power stations require auxiliary steam for widely differing further consumers (for example bypass flow 25 degasifiers, building heating, etc.).

This auxiliary steam is required in particular when the installation is not in use and when starting up and/shutting down the turbine sets, as well as during normal operation of the power station installation, for 30 example at the rated load.

When the installation is not in use, the gas turbine does not emit any hot exhaust gas, so that no operating steam, and no auxiliary steam either, can be provided by means of the waste heat boiler in this operating 35 situation for the steam turbine or for further steam consumers, as mentioned by way of example above.

In order to supply steam consumers such as these with auxiliary steam, an independent, heated auxiliary steam generator, which is completely isolated from the waste heat steam generator, is generally used in known power 5 stations.

Auxiliary steam generators such as these generate saturated steam, that is to say superheated steam, when the installation is not in use and during starting 10 up/shutting down, and this is supplied to the steam consumers mentioned above.

During normal operation of the installation, the auxiliary steam that is required is generated, for 15 example, in a low-pressure section of the waste heat steam generator while, during normal operation, the auxiliary steam generator, which is designed such that it is separate from the waste heat steam generator, is not necessarily required, since the auxiliary steam can 20 be generated in the waste heat steam generator itself, from the hot exhaust gas that is introduced into it.

Dispensing with the auxiliary steam generator in a known power station installation is often possible only 25 in exceptional situations (for example in the case of pure basic load power stations which operate virtually around the clock and in which hot exhaust gas is therefore available all the time for auxiliary steam generation), and leads to considerable restrictions on 30 the flexibility of the installation since, for example, a complete installation shut down or operation at a very low load leads to loss of the auxiliary steam generation.

35 Further requirements for power station installations include heating up, keeping hot and maintaining the

- 2a -

pressure in the waste heat boiler and the fresh steam lines, as well as heating up and keeping hot the steam turbine at a temperature and a pressure level which are as high as possible; the stated requirements should 5 also be satisfied when the installation is not in use and while the turbines are being started up or shut down.

By way of example, the starting-up time for a known power station installation is dependent on the pressure and the temperature of the auxiliary steam.

5 The invention is thus based on the object of specifying a waste heat steam generator which allows flexible operation of the power station installation, and which can be designed to be particularly cost-effective.

10

According to the invention, the object is achieved by a waste heat steam generator for a gas and steam power station, which has a waste heat boiler to which exhaust gas from a gas turbine can be supplied, and which also 15 has at least one evaporator, which is arranged in the waste heat boiler, in order to generate operating steam for a steam turbine, wherein the waste heat boiler can be supplied with flue gas from a heating device, and at least a portion of the flue gas can be extracted at at 20 least one point from the waste heat boiler, and can be fed back to an inlet opening into the waste heat boiler.

In consequence, in a waste heat steam generator 25 according to the invention, at least a portion of the flue gas which leaves the waste heat boiler and/or which is extracted from the waste heat boiler at at least one point upstream of its outlet opening is carried in a flue gas circuit.

30 The heating device has, for example, a burner to which fuel and combustion air, as well as the portion of the flue gas as the medium to be heated, are supplied. The flue gas which has been heated by means of the heating device is then (once again) introduced into the waste 35 heat boiler, where, by means of exchange of heat, it

- 3a -

emits energy to the evaporator, so that the latter can generate auxiliary steam. The auxiliary steam can then, for example, be extracted from a steam drum that is part of

- 4 -

the evaporator, with consumers being supplied with auxiliary steam, as well as fresh steam lines and/or the steam turbine.

5 The flue gas, which has been cooled down while it flows through the waste heat boiler, is passed after extraction of at least a portion back to the inlet opening of the waste heat boiler, and is heated by means of the heating device.

10 The heating device is in this case preferably designed for steam loads which correspond to a required auxiliary steam load and/or an amount of heat required for heating fresh steam lines and/or the steam turbine.

15 A waste heat steam generator according to the invention ensures the auxiliary steam supply in particular in operating situations in which no hot exhaust gas, or only a small amount of hot exhaust gas, is available  
20 (for example when not in use, during starting up/shutting down etc.). Furthermore, this avoids the heating system being designed to be unnecessarily powerful, since there is no need to use it to generate the operating steam for the steam turbine.

25 Furthermore, the auxiliary steam which is required during normal operation of the power station installation can alternatively or in addition to the heating system be produced by means of the exhaust gas.

30 Excess flue gas may, for example, be passed into a chimney after leaving the waste heat boiler.

35 The amount of auxiliary steam generated by means of a waste heat steam generator according to the invention is advantageously determined by controlling the flow

- 4a -

rate of flue gas which is introduced into the waste heat boiler, for example by means of a control valve, which is arranged upstream of and/or downstream from a burner

- 5 -

for the heating device, in the flow direction of the flue gas.

The temperature of the flue gas of a waste heat steam  
5 generator according to the invention is set in particular by the flow rate of fuel which is supplied to the heating device. Increasing the fuel supply in this case results in an increase in the combustion temperature, and thus in an increase in the heating-up  
10 temperature for the flue gas.

The amount of combustion air which is required by the heating device for a waste heat steam generator according to the invention is advantageously  
15 controlled, for example by means of a further control valve which is connected in an air supply line to the heating device.

Embodiments of the invention relate to the  
20 configuration of a circulation circuit for the flue gas, and to the arrangement of the heating device (contained in the dependent claims 2-4).

In a further embodiment, the waste heat steam generator  
25 has at least two evaporators.

Waste heat boilers equipped in this way and having evaporators at different temperature levels are known from a large number of power station installations.  
30 The required auxiliary steam can then be extracted from that evaporator that is arranged at the temperature level which is suitable for the purpose of auxiliary steam generation, for example that evaporator which generates the operating steam for a low-pressure stage  
35 of the steam turbine during operation of the power station installation.

- 6 -

The at least one portion of the flue gas can in this case preferably be extracted from the waste heat boiler upstream of at least one of the evaporators in the flow direction of the flue gas.

5

The energy content of the flue gas at an extraction point such as this has not yet been greatly reduced.

In a further advantageous refinement of the invention,  
10 the at least one portion of the flue gas can be extracted from the waste heat boiler at or in the flow direction of the flue gas downstream from its outlet opening.

15 In this case, the flue gas has passed completely through the waste heat boiler before the at least one portion of the heating device is fed back.  
This ensures that virtually the entire amount of flue  
gas which is introduced into the waste heat boiler can  
20 interchange heat with the evaporator from which the auxiliary steam is extracted.

In order to control the auxiliary steam generation, the heating device advantageously has at least one control  
25 device for adjustment of the temperature and/or the flow rate of the flue gas.

In this embodiment, the respectively required amount and energy content of the auxiliary steam can be  
30 generated specifically in each operating situation of the power station.

Additional embodiments of the invention relate to the role of the auxiliary steam as working or heating  
35 steam, in which case the auxiliary steam can preferably be extracted in every operating situation, that is to say in particular even while the installation is not in use,

- 7 -

and while the installation is being started up and shut down (contained in the dependent claims 9-11).

Two exemplary embodiments of the invention will be  
5 described in more detail in the following text.

In the figures:

10 Figure 1 shows a schematic illustration of the waste heat steam generator according to the invention, having a heating device connected in a circulation circuit, and

15 Figure 2 shows an alternative embodiment of the invention, with a heating device connected in a circulation circuit.

The arrangement of a waste heat steam generator 1 according to the invention is illustrated schematically in Figure 1.

20 In order to assist clarity, the waste heat steam generator 1 is in this case illustrated in a horizontal position. In a physical embodiment, the waste heat steam generator 1 may, of course, be arranged  
25 vertically, that is to say with an essentially vertical extent.

30 The waste heat steam generator 1 has a waste heat boiler 3, into which exhaust gas 7 from a gas turbine 5 is introduced through an inlet opening 4 in the waste heat boiler 3.

35 In the present exemplary embodiment, heat exchanger surfaces of three evaporators are arranged in the waste heat boiler 3 specifically of a high-pressure evaporator 15, of a medium-pressure evaporator 13 and of a low-pressure evaporator 11.

- 8 -

Each of the evaporators 15, 13, 11 which have been mentioned has a high-pressure drum 31, a medium-pressure drum 29 and a low-pressure drum 27.

5 The drums 31, 29, 27 are in this case each supplied with feed water 17 via a line which is not shown in any more detail.

10 A heating device 43 which has a burner 33 (which is operated by means of fuel 35), a fan 39 and control valves 37, 41 is arranged effectively in parallel with the waste heat boiler 3 in a feedback line 44. This results in a circulation circuit 50 being formed by a heating path 52, 53 through the waste heat boiler 3 and 15 the feedback line 44.

20 The heating by means of the burner 33 results in flue gas 9 which is introduced into the waste heat boiler 3. The flue gas 9 passes through the waste heat boiler 3 along the heating path 52, 53, in the process coming 25 into contact with the heating surfaces of the evaporators 15, 13, 11.

25 Feed water 17 is introduced into the areas inside the heating surfaces of the evaporators 15, 13, 11 by means of the respective steam drum 31, 29 or 27, so that steam can be generated by means of heat exchange. High-pressure steam 25 can thus be extracted from the high-pressure evaporator 15, medium-pressure steam 23 from 30 the medium-pressure evaporator 13, and low-pressure steam 21 from the low-pressure evaporator 11. These respective steam elements 25, 23 and 21, which are produced by means of the evaporators 15, 13, 11, can then be supplied in a manner which is not illustrated 35 in any more detail to the appropriate pressure stages of a steam turbine.

Furthermore, auxiliary steam 19, for example for the auxiliary steam consumers in the power station or for heating installation components such as fresh steam lines, can be extracted from the low-pressure 5 evaporator 11, in particular from its low-pressure drum 27.

Auxiliary steam 19 can be extracted even in operating situations in which no exhaust gas 7, or only a small 10 amount of exhaust gas 7, is available from the gas turbine 5, for example when not in use or while the gas turbine 5 is being started up or shut down.

The energy which is required for generation of the auxiliary steam 19 is provided, in particular in 15 operating situations such as this, by the flue gas 9 which is generated by means of the heating device 43 and is passed through the waste heat boiler 3.

Whilst the flue gas 9 leaves the waste heat boiler 3 20 through its outlet opening 45, at least a portion of it is fed back by means of the feedback line 44 to the inlet opening 4 of the waste heat boiler 3; a flue gas circuit is thus formed in a waste heat steam generator according to the invention, which results in particular 25 in the energy contained in the flue gas 9 being utilized particularly well.

Alternatively or in conjunction, the at least one 30 portion of the flue gas 9 can also be extracted at a point other than the outlet opening 45 from the waste heat boiler 3, and can be fed back to the heating device 43. A suitable point in this case is, for example, a point in the flow direction of the flue gas 9 upstream of the medium-pressure evaporator 13, while

- 9a -

the flue gas 9 has not yet been very greatly cooled down; this option for alternative or additional feedback of the flue gas 9 is illustrated by dashed lines in the figure.

- 10 -

The temperature of auxiliary steam 19 that is generated can be set by variation of the flow rate of the fuel 35 which is supplied to the burner 33; the flow rate of the combustion air 47 which is required for operation 5 of the burner 33 is advantageously controlled by means of a control valve 41 which is connected in an air supply line to the burner.

Furthermore, the flow rate of the auxiliary steam 19 to 10 be generated can be adjusted by means of a further control valve 37, which is connected upstream of the burner in the flow direction of the flue gas 9, in order to adjust the flow rate of the flue gas 9 that is supplied to the burner; the flue gas 9 can be supplied 15 to the burner 33 by means of a fan 39.

Figure 1 shows, schematically, the method procedure for auxiliary steam generation in a waste heat steam generator 1 according to the invention, based on the 20 example of a waste heat steam generator 1 for a three-pressure gas and steam process with intermediate superheating. The invention can also be used for other processes (for example for a two-pressure process with intermediate superheating, etc.).

25 In one method of operation of the waste heat steam generator 1 according to the invention, slides which are connected in the supply lines to the high-pressure and medium-pressure evaporators can be closed so that 30 no steam is generated in these pressure stages. The cooled-down flue gas is tapped off at the outlet opening 45, with at least a portion of the flue gas 9 being fed back to the inlet opening 4. Excess flue gas 35 is emitted either via an existing chimney or via a separate chimney with a suction path.

- 11 -

The burner 33 heats the flue gas 9 by combustion, for example, of natural gas to the temperature required at the inlet to the waste heat steam generator 1; the required combustion air 47 is supplied, for example, 5 via a combustion air fan.

The flow rate of auxiliary steam is controlled by variation of the flue gas flow rate flowing through the waste heat steam generator, for example by means of the 10 control valve 37.

The flue gas temperature is controlled by variation of the fuel flow rate.

15 The further control valve 41 is used, for example, to control the required combustion air flow rate.

If a separate chimney with a suction path is used, the pressure on the flue gas side of the system can be 20 controlled, for example, by means of an additional control valve.

In an alternative method of operation of the waste heat steam generator 1 according to the invention, the 25 slides which have already been mentioned are opened, so that steam is generated in all of the pressure stages. The steam from the high-pressure evaporator 15 and/or from the medium-pressure evaporator 13 of the waste heat steam generator 1 may, for example, be used to 30 heat up/keep hot a fresh steam line for the steam turbine in the power station.

Figure 2 shows an alternative embodiment of a waste heat steam generator 1 according to the invention in 35 which, in contrast to Figure 1, the heating device 43 is not connected in but to the feedback line 44.

- 12 -

Investigations have shown that an arrangement of a heating device 43 such as this results in advantages since, for example, the recirculation circuit can be maintained even in the event of temporary malfunctions 5 of the heating device 43 - although possibly with a reduced energy content in the flue gas 9 in some circumstances. Furthermore, with this arrangement, the volume flow of the flue gas 9 in the feedback line 44 is not interfered with by any intermediate component, 10 thus assisting smooth operation; in the embodiment shown in Figure 1, the recirculation circuit can likewise be maintained in the event of a malfunction of the heating device 43, provided that the feedback line 44 is not closed inadvertently as a result of the 15 malfunction.

The fan 39 is connected in the feedback line 44 and carries out the function of a recirculation fan.

20 Control devices for adjusting the flow rate of recirculated flue gas 9 can also be connected in the feedback line 44.

A waste heat steam generator according to the invention 25 results, inter alia, in the following advantages:

- there is no need for a separate auxiliary steam generator,
- the waste heat steam generator can be kept hot 30 even when the system is not in use, so that there is no need for any otherwise required frost protection measures,
- the waste heat steam generator can be kept at a relatively high pressure while not in use, so that 35 the stress loads on components with thick walls as

- 12a -

a result of temperature changes (during heating up and cooling down) can be considerably reduced when starts occur frequently, and

- 13 -

- the fresh steam line for the steam turbine and the steam turbine itself can be kept hot and/or can be heated up, thus considerably shortening the starting-up times for the overall installation, which, *inter alia*, leads to a considerable reduction in the exhaust gas emissions.

5